NuMI Target Info for MINERVA Run Plan Review

Goal - present impact of MINERVA Run Plan on NuMI:

- Possible extra target construction
- Extra beam-off days for reconfiguration
- Schedule impacts
- Manpower impacts

Plus some documentation on MINOS/NOVA targets

Since we have limited statistics on target reliability,
will present NuMI target history to flesh out risk assessment

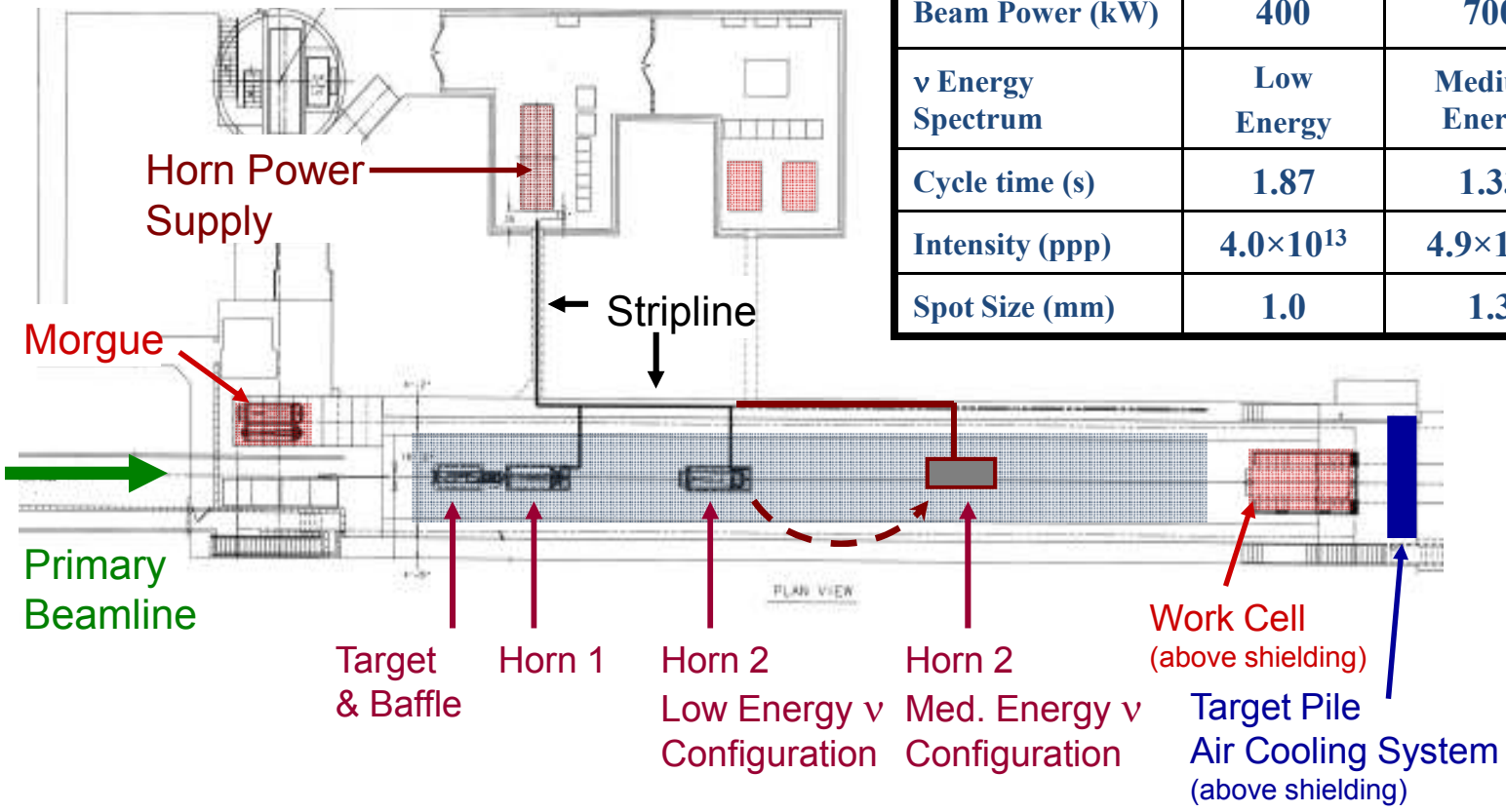
Would like to use this Review to confirm going ahead with construction of NT06 – believe NT06 makes sense irrespective of whether MINERVA runs post 2012 shutdown or not

My "hat" here is NuMI beam-line customer service, not representing MINERVA or MINOS or NOVA

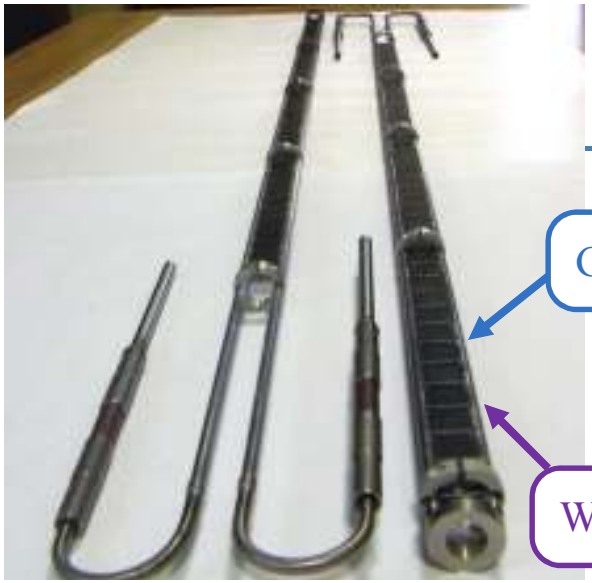
Many slides "borrowed" without attribution from Mike Martens, Kris Anderson, Mike McGee …

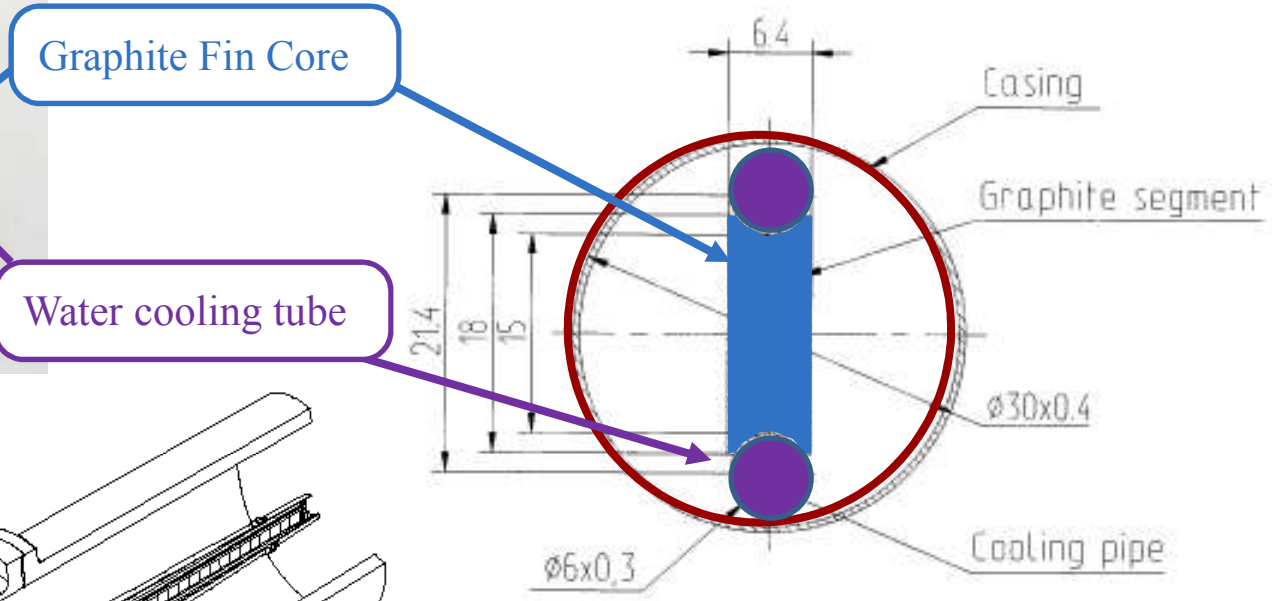
Re-configuration for NOνA : move Horn 2, higher beam power

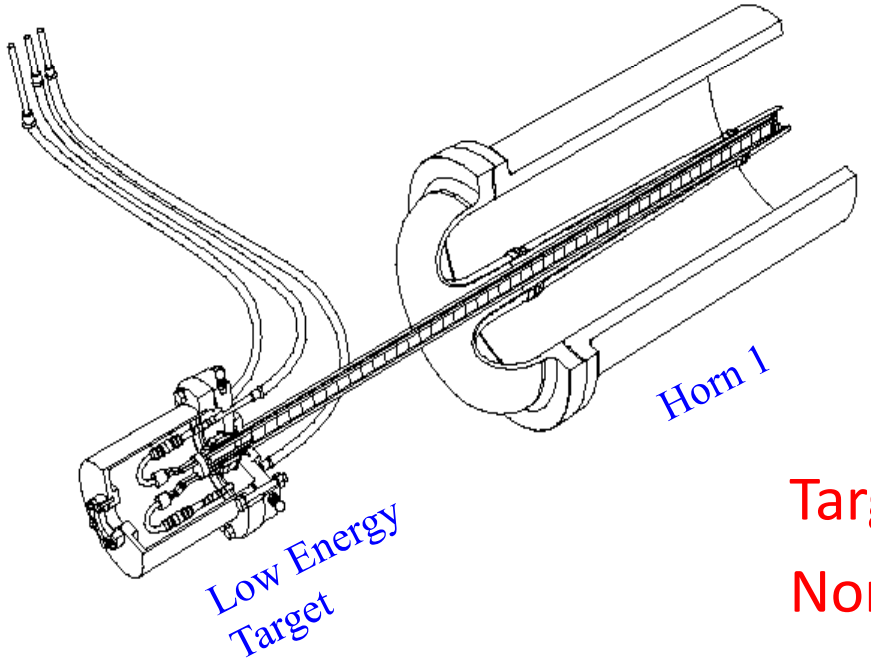
	NuMI Design	NOνA
Beam Power (kW)	400	700
ν Energy Spectrum	Low Energy	Medium Energy
Cycle time (s)	1.87	1.33
Intensity (ppp)	4.0×10^{13}	4.9×10^{13}
Spot Size (mm)	1.0	1.3



MINOS LE Target



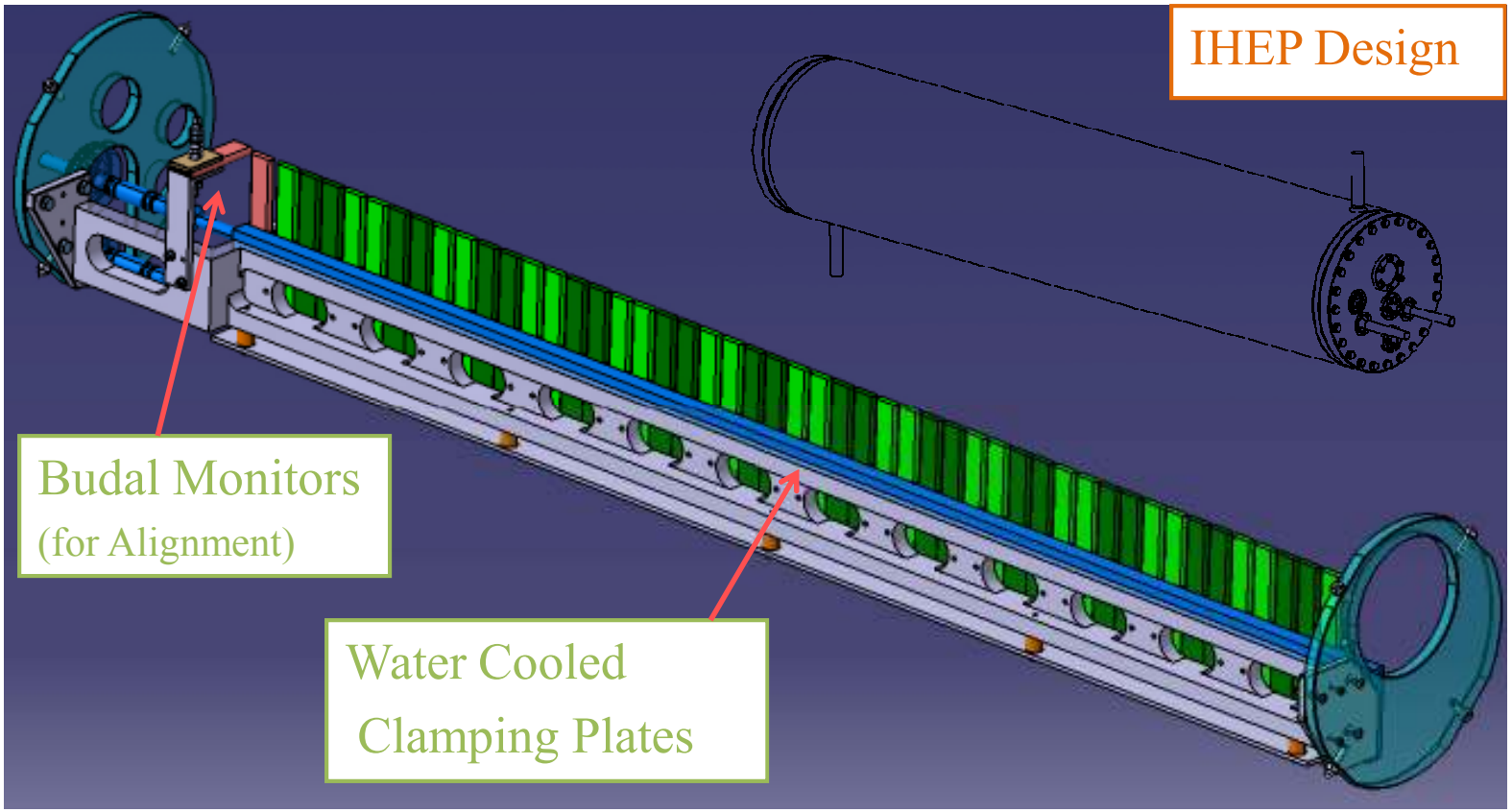




Target must fit into horn

Nominal max. beam power 400 kW

NOVA ME Target



Nominal max. beam power 700 kW

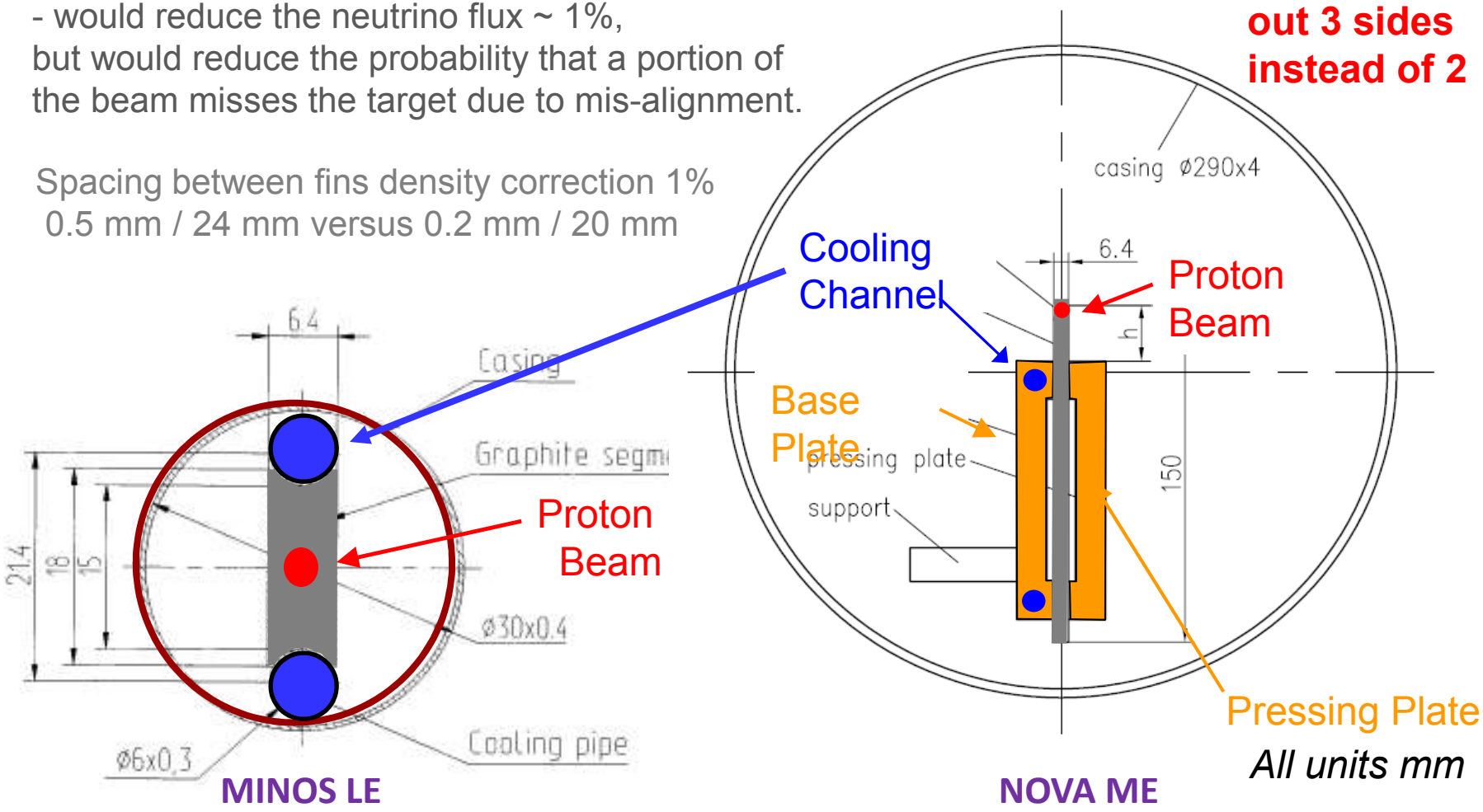
Target cross section comparison

- how much change does Monte Carlo have to correct for ?

MINOS beam spot size of 1.1 mm RMS is increasing to 1.3 mm for NOVA,
so are considering increasing 6.4 mm target width to ~ 7.5 mm
- would reduce the neutrino flux ~ 1%,
but would reduce the probability that a portion of
the beam misses the target due to mis-alignment.

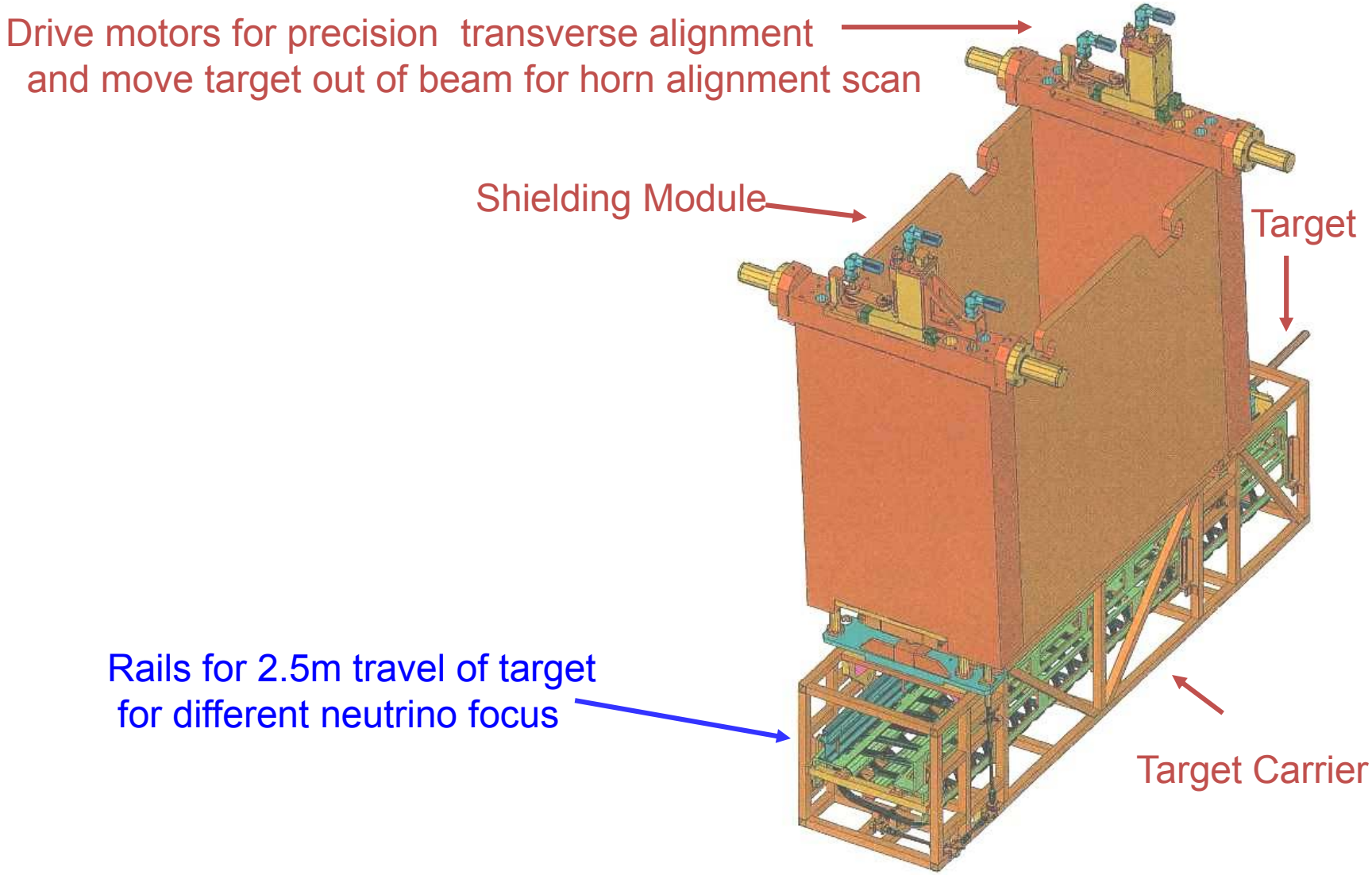
Spacing between fins density correction 1%
0.5 mm / 24 mm versus 0.2 mm / 20 mm

Pions come out 3 sides instead of 2

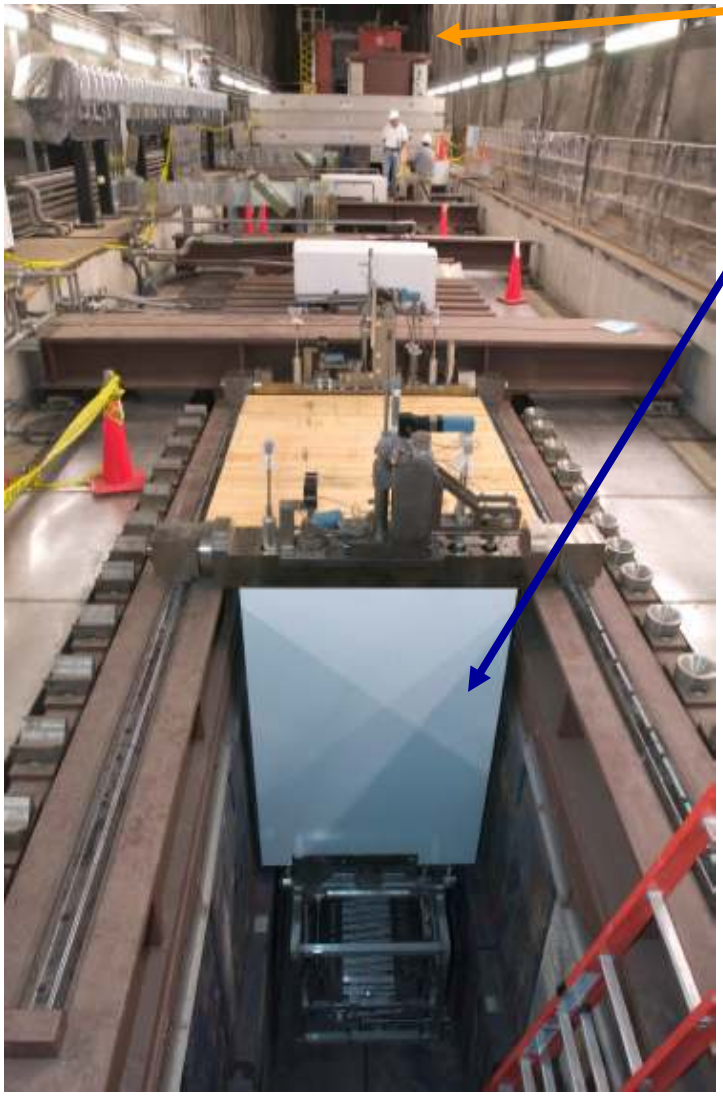


All units mm

MINOS target carrier on shielding module

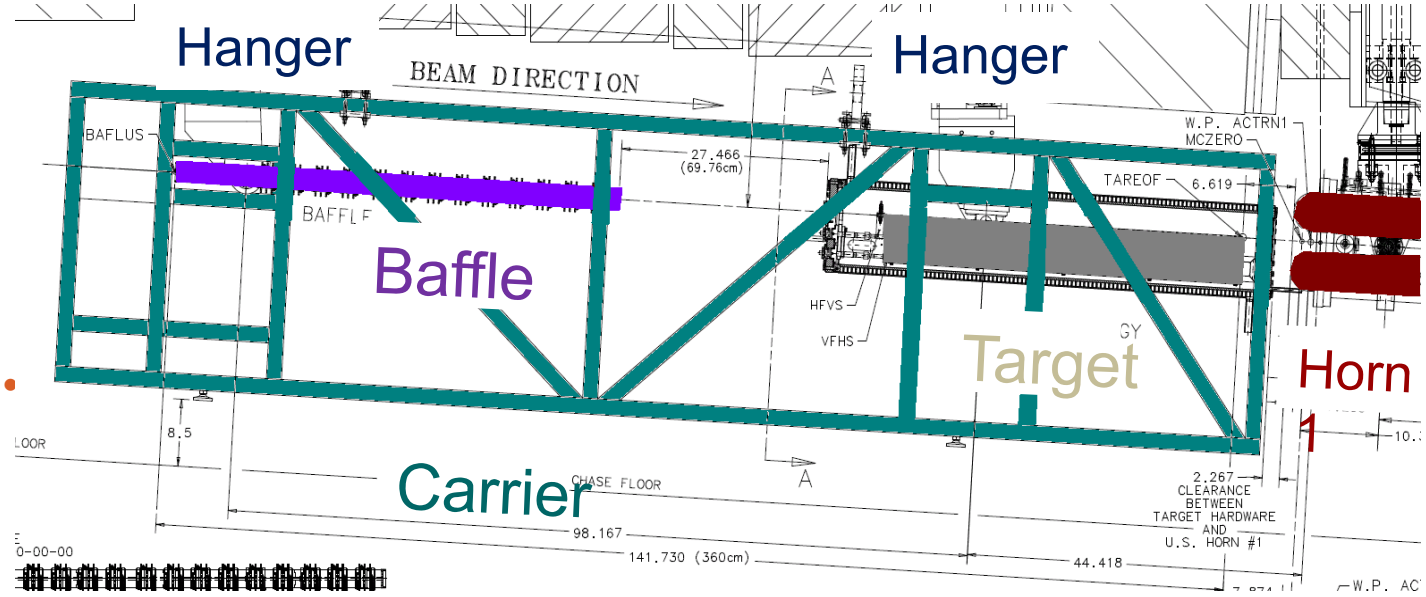


Target as installed in NuMI



1st target being removed

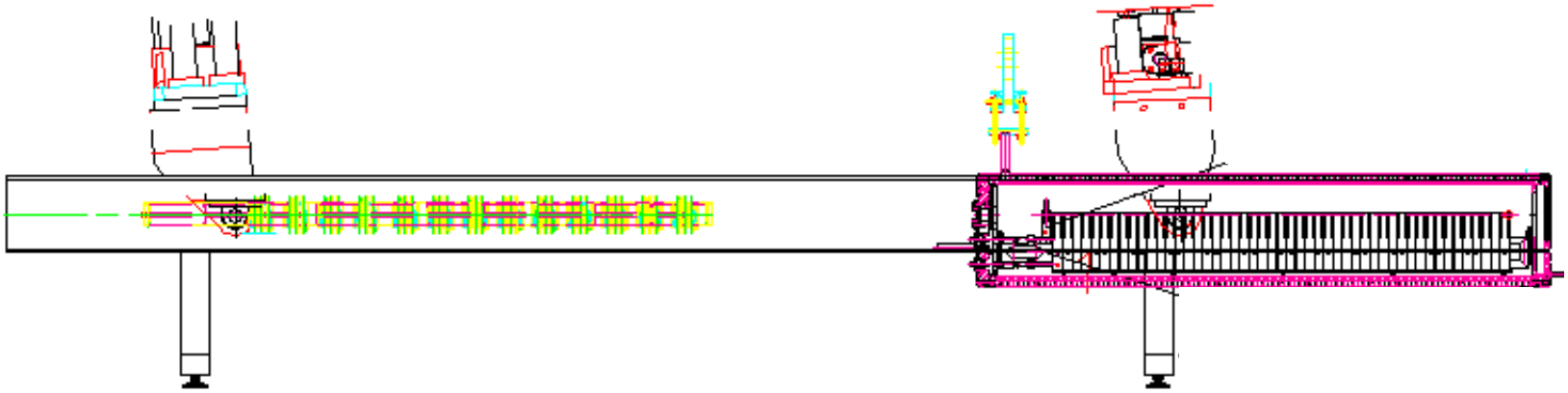
NOVA Medium Energy Target Layout

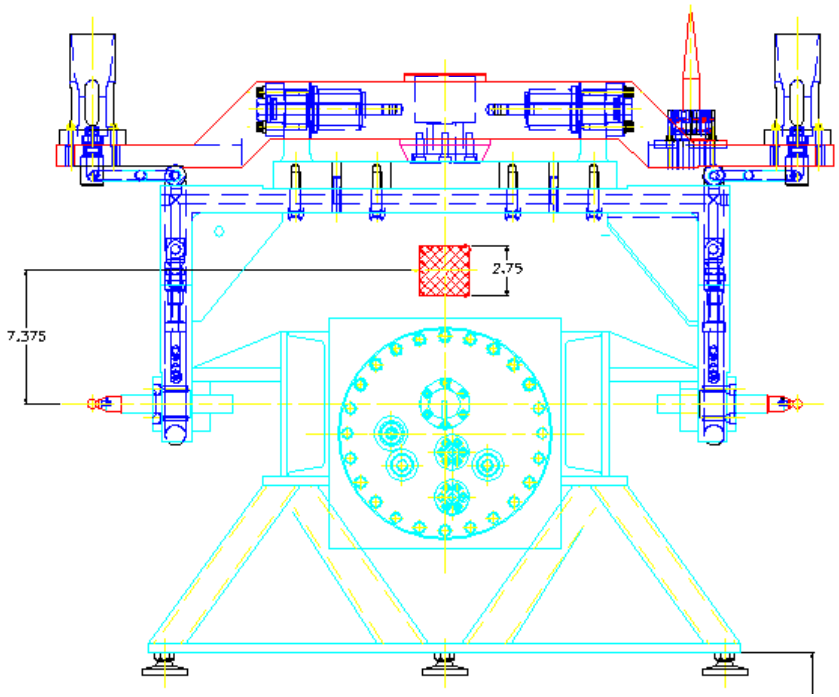


But carrier is being redesigned

NOVA target carrier concept: simple strong-back of C beams

No target motion along beam-line – several months of engineering invested so far





NUMI Target History

NT01 suffered a near-fatal infant mortality incident – water cooling leak onto graphite fin

It was rejuvenated by increasing helium pressure in target can (39 day downtime)

(helium leak into water rather than water leak into helium)

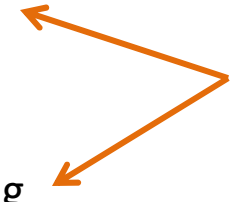
Autopsy next year might let us determine cause of failure.

NT01 was removed at 1.6e20 POT because

Z-drive motion froze in HE location

NT02 was removed at 6.0e20 POT because

neutrino yield was gradually decreasing



The two effects included in target schedule planning

NT03 is running, 0.7e20 POT so far

NuMI target experience

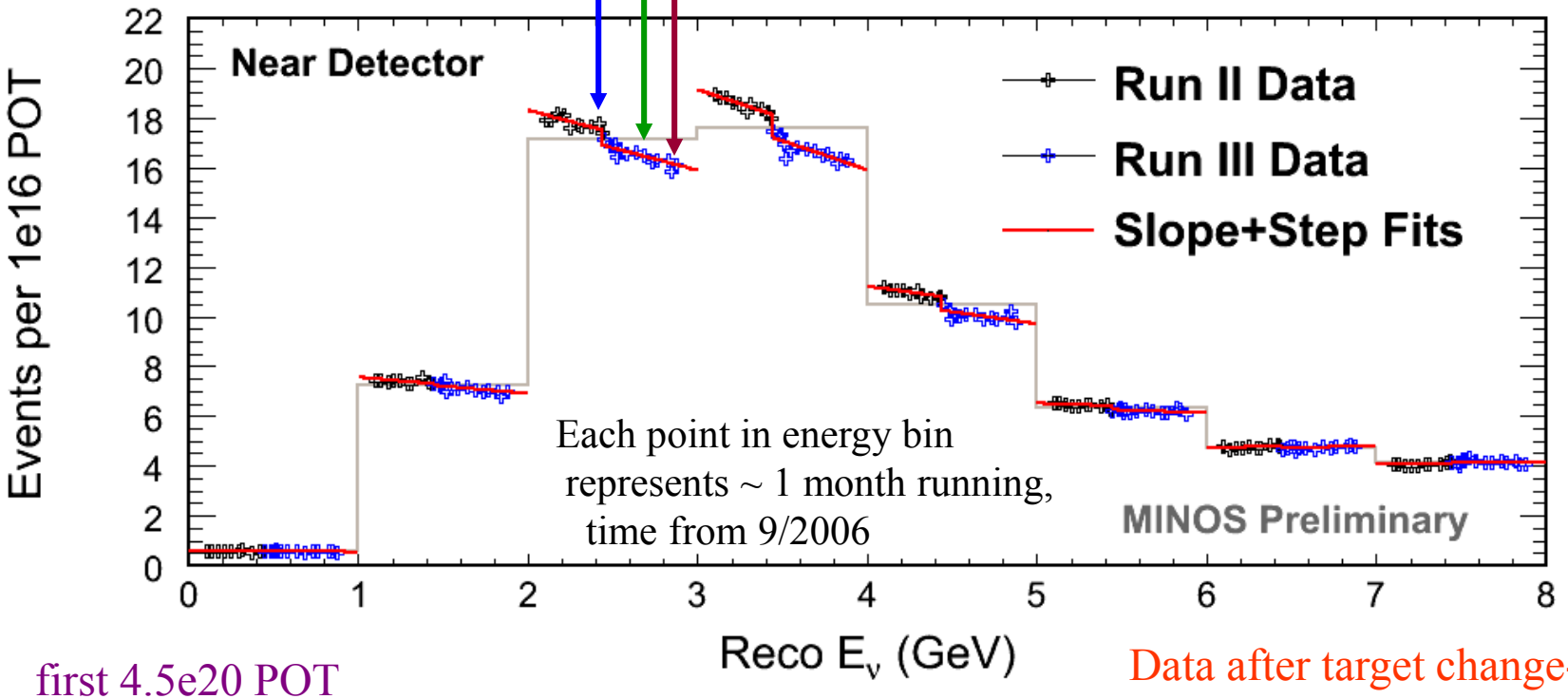
(ZXF-5Q amorphous graphite)

Gradual decrease in neutrino rate attributed to target radiation damage

Decrease as expected when decay pipe changed from vacuum to helium fill

No change when horn 1 was replaced

No change when horn 2 was replaced



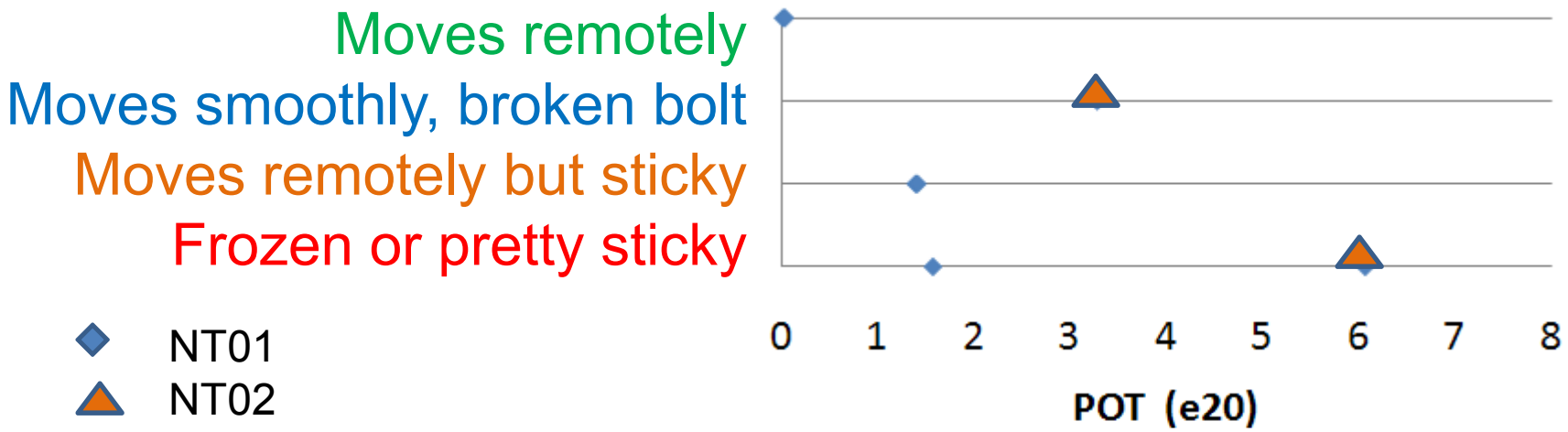
first 4.5e20 POT

of total 6.1e20 POT on NT-02 shown on this plot

= 0.7 DPA (MARS M.C.)

Data after target change-out
not fully analyzed yet,
but indicates flux regained

Target Z-drive (2.5 m motion) history



NT01 motion failed on frozen drive-screw pillow block roller bearing that corroded

- have switched to a graphite bushing

NT02 motion failed on broken high strength bolts at couplers

- have switched to stainless steel bolts

So have corrected all previous failure modes

Have also modified many other parts, so much better chance of longer term motion.

But no experience with new modifications, so no guarantee.

NT01 Frozen drive shaft

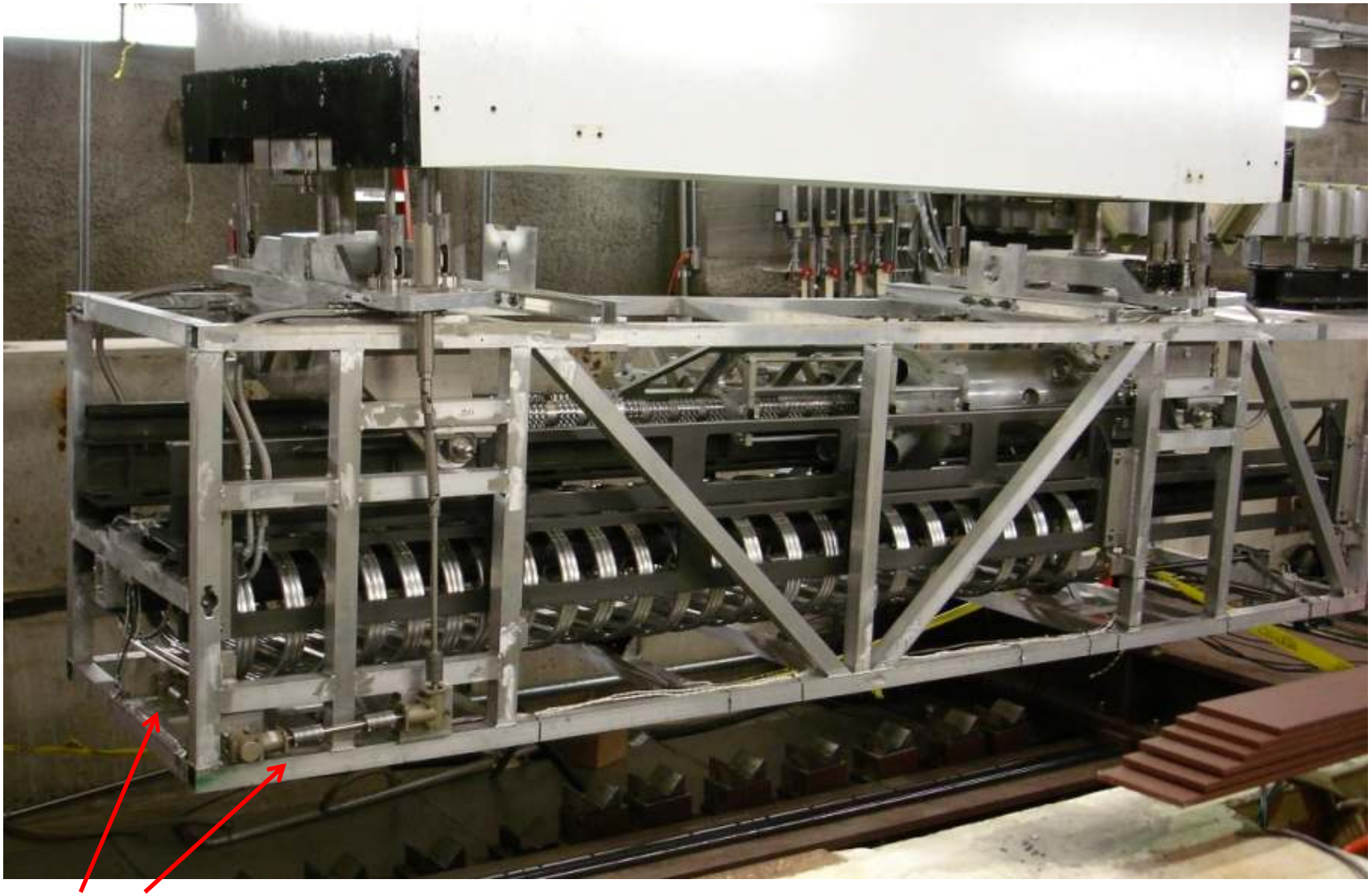
After month-long test in High Energy position
drive shaft would not rotate to move target into Low Energy position

Changed to spare target + carrier (NT02)

NT03 onward, changed to graphite bushing

Old jammed pillow-block

NT01 Target carrier on module



On NT02, high strength bolts on Z-drive couplers snapped, (hydrogen embrittlement ?)

Replaced broken bolts first time this happened, then used remote motion

Target carrier revisions (page 1)

Target	*NT-02*	*NT-03*	*NT-04*
Upstream bushing block (Carries radial and thrust load of lead screw)	Greased roller bearings	Graphite bushing with stainless steel thrust washers to control axial backlash	Graphite bushing with anodized aluminum thrust washers to control axial backlash
Downstream busing block (Carries radial lead screw load only)	Greased roller bearings	Graphite bushing	Graphite bushing
Target Carrier Rail BL (Round Rail)	Greased Needle bearings	Greased needle bearings	Graphite friction bearing
Target Carrier Rail BR (Flat Rail)	Greased Needle bearings	Greased needle bearings	Graphite friction bearing
Fixed downstream bearing block	YES- Downstream bushing block wrenched tight to bracket	NO, ~.010 axial clearance to bracket to let the bushing float in bolt hole clearance for expansion/self alignment purposes	NO, ~.010 axial clearance to bracket to let the bushing float in bolt hole clearance for expansion/self alignment purposes

Target carrier revisions (page 2)

Other miscellaneous changes done to both NT03/NT04

- All hardened steel screws, bolts, nuts, and washers have been removed and replaced with 316 Stainless steel. Along with that all 18-8 stainless steel has also been replaced with 316 Stainless steel where applicable.
- The downstream bearing block has been set with a .010 clearance between the mount and the actual bearing block.
- The screw drive assembly has been updated to include keyways to further ensure the couplers do not slip on the drive shafts.
- The telescoping drive housing has also been revised to be stainless steel.
- All steel roll pins have been replaced with stainless steel dowel pins.

Schedule from Program Planning

Draft 2010-13 Fermilab Accelerator Experiments' Run Schedule

Typically Revised Annually - This Version from October, 2009

Calendar Year		2010	2011	2012	2013
Tevatron Collider		CDF & DZero	CDF & DZero	OPEN	OPEN
Neutrino Program	B	MiniBooNE	MiniBooNE		OPEN
		OPEN	OPEN		MicroBooNE
	MI	MINOS	MINOS		OPEN
		MINERvA	MINERvA		MINERvA
		ArgoNeuT			
				NOvA	NOvA
SY 120	MT	Test Beam	Test Beam		Test Beam
	MC	OPEN	OPEN		OPEN
	NM4	E-906/Drell-Yan	E-906/Drell-Yan		E-906/Drell-Yan

This draft schedule is meant to show the general outline of the Fermilab accelerator experiments schedule, including unscheduled periods.

Major components of the schedule include shutdowns:
In Calendar 2010, a 4-6 week shutdown for maintenance is shown.
In Calendar 2011, no shutdown for maintenance is shown.
A 2012-3 11-month shutdown is shown to upgrade the proton source and change the NuMI beam to the Medium Energy (ME) config.

RUN/DATA

STARTUP/COMMISSIONING

INSTALLATION

M&D (SHUTDOWN)

19-Oct-09

Target Degradation Scenario up to NOVA shutdown

start	end	days	POT/day (e20)	POT (e20)	Integral POT e20
9/22/2009	11/30/2009	70	0.010	0.70	0.7
12/1/2009	7/15/2010	227	0.010	2.27	2.97
7/16/2010	8/26/2010	42			2.97
8/27/2010	9/30/2011	400	0.010	4.00	6.97
10/1/2011	3/1/2012	153	0.012	1.84	8.81
Allow for 10% downtime horn/target replacement				-0.81	**8.00**

+ 0.9e20 POT after NOVA shutdown (?)
~ 15% change in peak if all with NT03

Assume target degradation linear 10% of ν per 6e20 POT, then relative to no target damage:

Integrated relative neutrino flux in peak	
Run NT03 to NOVA shutdown	93.3%
Change NT03 to NT04 July 2010 shutdown	96.2%
Change NT03 to NT04 in mid-run (2 wk down)	95.3%

Gain few/several % by changing target

What about systematic errors from running with degraded target ?

Estimate of systematic error from target degradation ?

Estimate of systematic error due to target hole for MINOS CC analysis found:

- Target hole is barely visible as the smallest systematic
- The matrix method extrapolation corrected well for the spectral change
- The effect on the oscillation measurement was negligible

Systematics for other analysis channels ?? Other Detectors ?? Don't have.

So don't have a statement of how often targets need to be changed out.

Previous Target Schedule
as of Nov 11, 2008 NuMI PMG

Have run NT02 for 4e20 so far with up to 10% effect on spectrum,
so should plan to replace target every 3e20 to 4e20 from now on

This version is tentative, and only for discussion; not yet a plan.

Calendar Year		2009	2010	2011	2012
Tevatron Collider		CDF & Dzero	CDF & Dzero		
Neutrino Program	B	MiniBooNE	MiniBooNE OPEN	OPEN	OPEN
		OPEN	OPEN	OPEN	OPEN
	MI	MINOS	MINOS	OPEN	OPEN
		MINERvA	MINERvA	MINERvA	MINERvA
					NOvA#
SY 120	MT	Test Beam	Test Beam	Test Beam	Test Beam
	MC	OPEN	OPEN	OPEN	OPEN
	?	E906#	E906#	E906#	OPEN

NT02 → ← NT03 → ← NT04 → ← NT05 with NT06 as spare

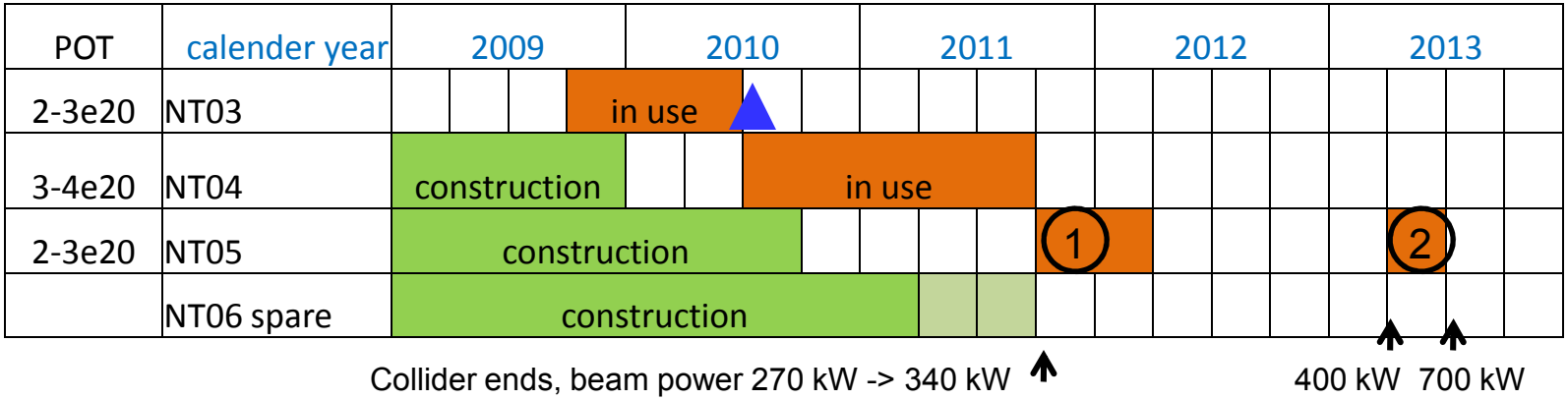
2013 – install ANU-T01, plan to replace every 6 months to 1 year (ANU 6e20 POT/year compared to 4e20 so far on NT02 with 5% to 10% effect on spectrum)
No MC yet on how depletion affects spectrum of NOVA
May be complicated by MINERVA desires

Some possible target usage scenarios (not proposals)

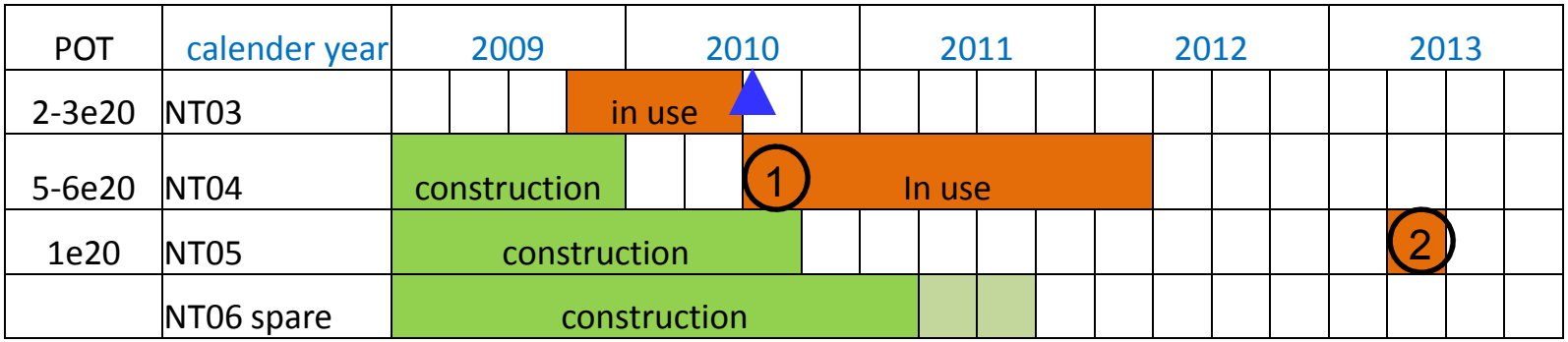
When are pre-NOVA special tests: Right after 2010 shutdown ? End of MINOS run ?

Assume:

- MINOS wants target change-out 2010 summer shutdown ▲
- Special test round ① starts Nov 2011 round ② Mar 2013
- An un-degraded target is desired for tests. (Spectrum + Z-drive fresh)



Alternate: do MINERVA special test round 1 right after 2010 shutdown



I. Pre-NOVA-shutdown MINERVA run schedule overhead

Depending on whether run is before or after collider turnoff , estimate is

0.9e20 POT/ 1.0e18 POT/day = 90 days running

or 0.9e20 POT/ 1.2e18 POT/day = 75 days running

Overhead:

14 days swap in new target, if not done in scheduled shutdown

2 days move LE010 to LE100	This direction keeps radiation of carrier minimized.
2 days move LE100 to LE150	Access each time to visually check target position.
2 days move LE150 to LE250	If target sticks, 2 to 3 weeks to un-stick or replace.
2 days move LE250 to LE010 *	*unless run through end of in LE250

~ 98 days total, IF include target swap for 1st assumed schedule, OR no swap for alternate.

II. Post NOVA-shutdown MINERVA run schedule overhead

Have been running around 270 kW, will be 400 kW during test (NO COLLIDER)
(could try 480 kW, but may not want to risk target)

1.0 E18 POT per day now x(400/270) = 1.5 E18 per day after ANU shutdown

0.9e20 POT/ 1.5e18 POT/day = 60 days running

Overhead:

1 shift beam alignment of MINERVA target

2 days move ME010 to ME100	This direction keeps radiation of carrier minimized.
2 days move ME100 to ME150	Access each time to visually check target position.
2 days move ME150 to ME250	If target sticks, 2 to 3 weeks to un-stick or replace.

14 days swap in NOVA target

~ 80 days total, plus whatever time accelerator uses to become stable.

Note (I.) + (II.) = 98 days + 80 days = 178 days total

NT06 estimated cost of target + baffle + carrier + assembly

NT03 cost report:

$ 67 k IHEP for target + baffle (~$15k more for NT06)

$ 99 k SWF + temp help, ~ 5/4 FTE year

$ 63 k FNAL machine shop

$ 49 k other M&S

$ 278 k total

For NT06, have already obligated cost of IHEP target + baffle (arrive January 2010), plus a few $k of M&S, so ~$100k M&S + $100k SWF to complete NT06

Are starting on NT05 carrier right now,
doing construction/QA of NT06 carrier at same time much better than NT06 later.

Input from Mechanical Support Dept. is that tech time to assemble NT06 should have minimal impact on other NUMI component construction.

Movable NOVA target ?

Gary asked interesting question of movable NOVA target,
allow ME100 to ME250 (not ME10) for MINERVA tests?

Could be done.

But design engineering resources are already dangerously stretched,
at the same time NOVA is asking us to move schedule up.
This would take significantly more engineering time,
putting the ANU schedule at risk. So I would advise against it.

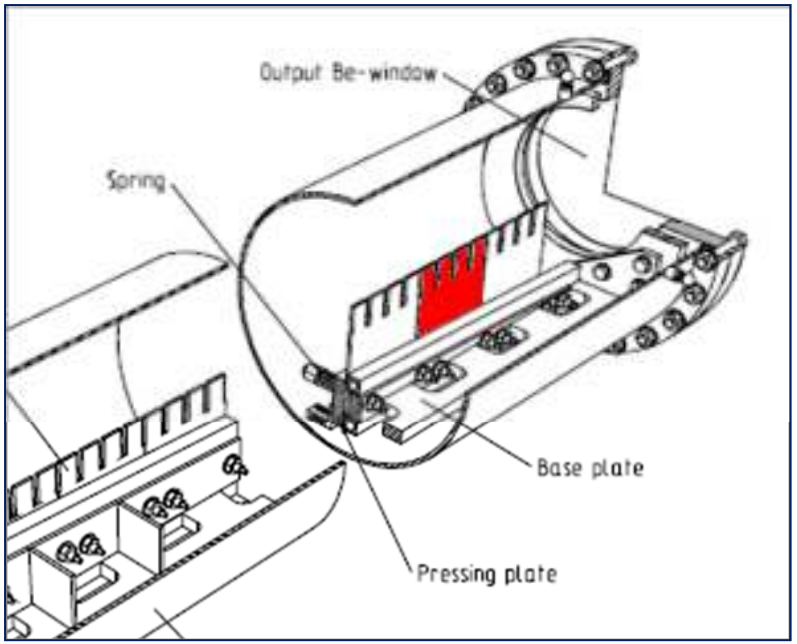
NT06 as NOVA fall-back

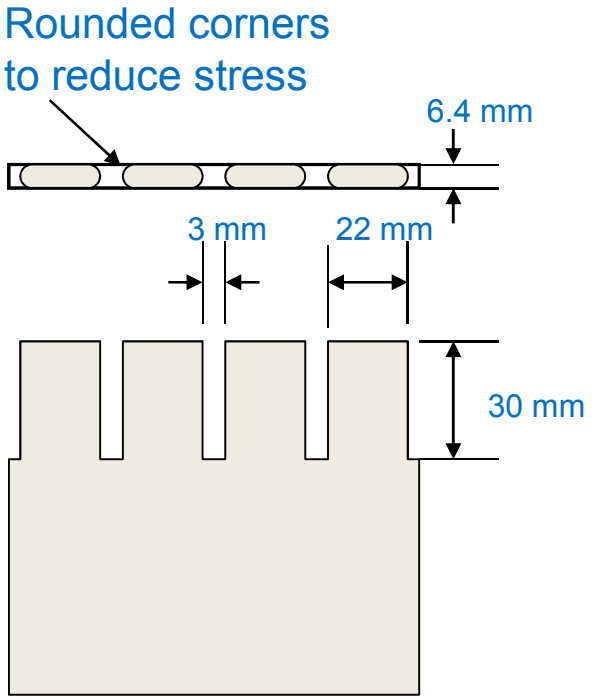
In case of NOVA target infant mortality or design failure,
having one or two MINOS style targets provides a fall-back,
allowing NOVA to run at 400 kW to 500 kW in ME location for a year
while building a re-designed NOVA target.

Both the MINOS and NOVA target carriers fit on the existing module;
swapping between the two styles should not be much work.

Backup Slides

Medium Energy Target





External to Horn 1
Graphite fins clamped with cooling plates
Beryllium windows
Filled with He to prevent oxidation

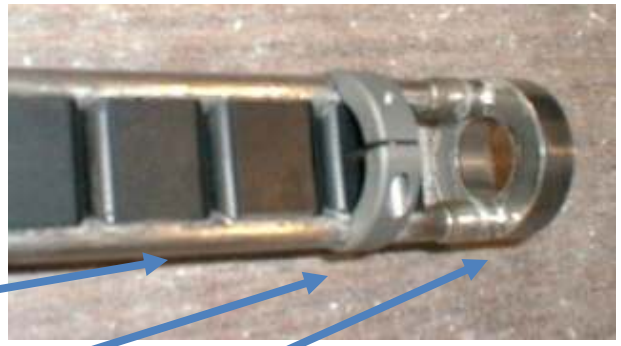
Twelve Plates of ZXF-5Q graphite
Same material as the low energy target
10 cm long × 15 cm high × 6.4 mm wide

NuMI Target

long, thin, slides into horn without touching

Graphite Fin Core, 2 int. len.

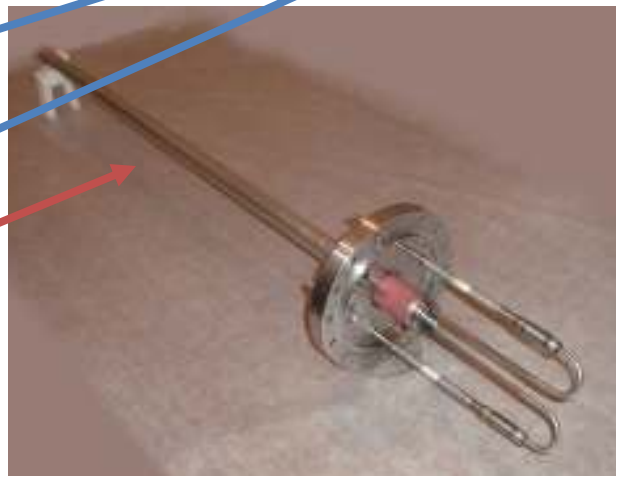
(6.4 mm x 15 mm x 20 mm) x 47 segments



Water cooling tube also provides mech. support

(steel soldered to graphite)

Anodized Al spacer (electrical insulation)



Water turn-around at end of target

0.4 mm thick Aluminum tube *(He atmosphere,*

Be windows at U.S. and D.S. ends)

Ceramic electrical isolation

Target NT-02 replaced with NT-03

FERMILAB
ACCELERATOR
DIVISION

DATE: 8/5/09	TIME: 1800	PURPOSE: movement survey	RWP #

NUMI Target
Beam Right

Point	Doserate @ 1 foot (mr/hour)	Doserate On Contact (mr/hour)
1	200	300
2	600	700
3	3000	3500
4	11300	45000

All Dose Rates Below N/A mR/hr Unless Noted.

Inst Type: teletector
Inst No: 6
Batt/Source Chk: sat
Cal. Due Date: 6/2010

LEGEND
Numbers appearing on map are mR/hr @ 1 ft readings unless denoted with symbols below
* = mR/hr @ contact
A = Air Sample ◯ = Wipe (F) = Floor wipe

Bkgd _____ cpm

Wipe # | Reading | Wipe # | Reading

N/A

Highest Dose Rate Found ~~11300~~ _____ mR/hr at 1 ft.

Note: RSO approval required to work in areas where it is: >100 mR/hr @ 1 foot OR >100 CCPM on a wipe.

Comments:

Surveyed By: Busch
Reviewed By: _____

REVISED 8/6/09

Once again, NT-02
target Z-drive
did not work

had to remove
target from horn by
by pulling with crane,

then in work cell
hand-crank
target back to
center for storage

Another failed
high-strength bolt

NT-03 has no
high strength bolts

Target was 45 r/hr,
hope to do autopsy 1 to 2 years from now

Remote 5-axis lift table

puts components on bottom of alignment modules in work cell

Numi target+baffle on lift table into beam

Target on module, ready to crane

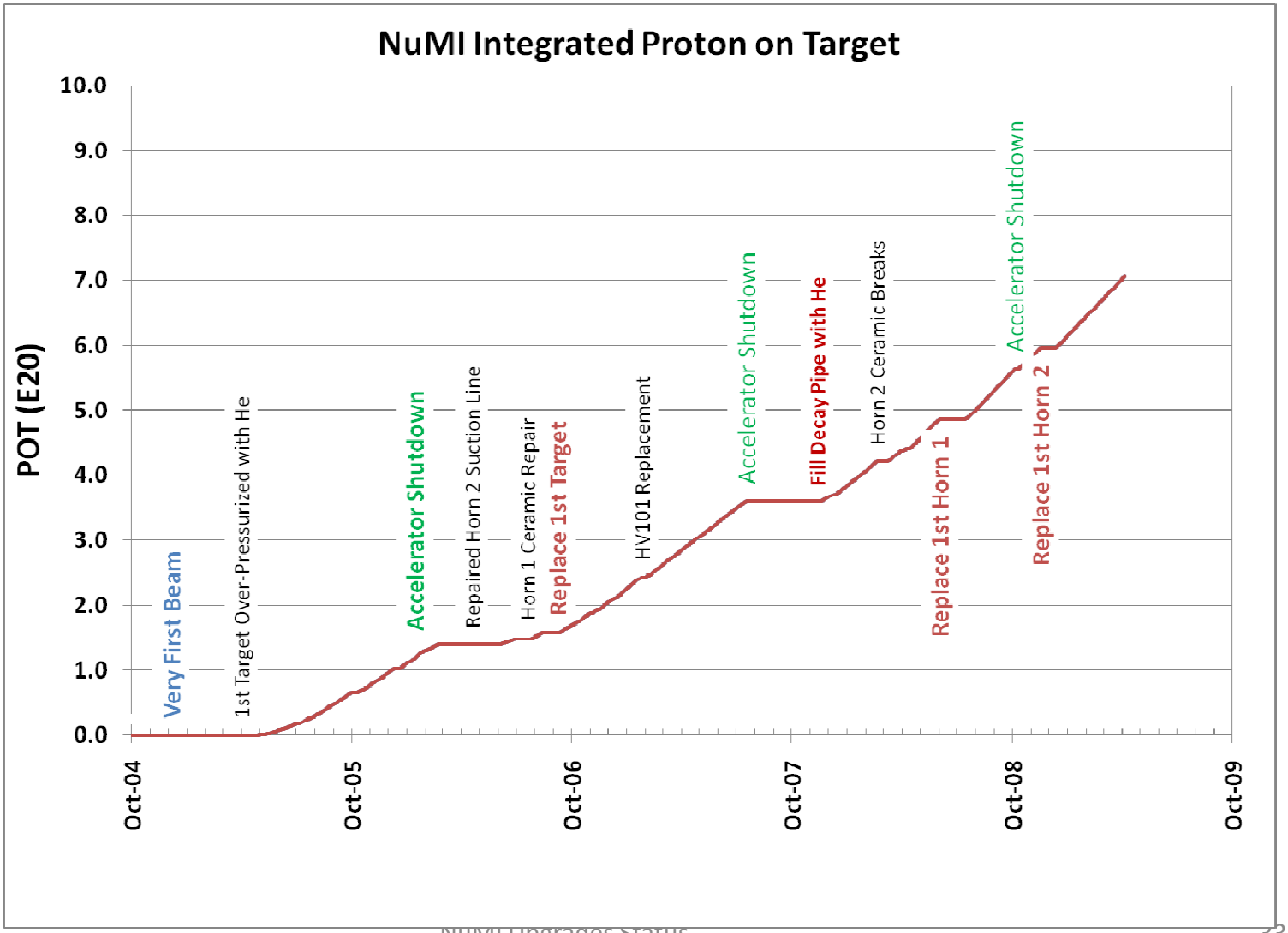
Target Alignment Survey

Survey of target tip relative to target tooling balls

After mount of target carrier to modul

Done through holes in work-cell lead-glass windows

Target Horn Repair & Retirement



Horn and Target Production